

# Direct Detection Doppler Lidar for Spaceborne Wind Measurement

C. Laurence Korb<sup>1</sup> and Cristina Flesia<sup>2</sup>

<sup>1</sup>NASA Goddard Space Flight Center, Laboratory for Atmospheres, Code 912  
Greenbelt, MD 20771  
Phone: 301-286-6233  
FAX: 301-286-1762  
korb@agnes.gsfc.nasa.gov

<sup>2</sup>Department of Applied Physics, University of Geneva  
20, rue de l'Ecole-de-Medecine CH-1211  
Geneve, Switzerland

IN-47  
047-176  
P 2

Aerosol and molecular based versions of the double-edge technique can be used for direct detection Doppler lidar spaceborne wind measurement. The edge technique<sup>1,2</sup> utilizes the edge of a high spectral resolution filter for high accuracy wind measurement using direct detection lidar. The signal is split between an edge filter channel and a broadband energy monitor channel. The energy monitor channel is used for signal normalization. The edge measurement is made as a differential frequency measurement between the outgoing laser signal and the atmospheric backscattered return for each pulse. As a result, the measurement is insensitive to laser and edge filter frequency jitter and drift<sup>3,4</sup> at a level less than a few parts in  $10^{10}$ .

We have developed double edge versions of the edge technique for aerosol<sup>5</sup> and molecular<sup>6</sup>-based lidar measurement of the wind. Aerosol-based wind measurements have been made at Goddard Space Flight Center and molecular-based wind measurements at the University of Geneva. We have demonstrated atmospheric measurements using these techniques for altitudes from 1 to more than 10 km. Measurement accuracies of better than 1.25 m/s have been obtained with integration times from 5 to 30 seconds. The measurements can be scaled to space and agree, within a factor of two, with satellite-based simulations of performance based on Poisson statistics.

The theory of the double edge aerosol technique is described by a generalized formulation which substantially extends the capabilities of the edge technique. It uses two edges with opposite slopes located about the laser frequency at approximately the half-width of each edge filter. This doubles the signal change for a given Doppler shift and yields a factor of 1.6 improvement in the measurement accuracy compared to the single edge technique. The use of two high resolution edge filters substantially reduces the effects of Rayleigh scattering on the measurement, as much as order of magnitude, and allows the signal to noise ratio to be substantially improved in areas of low aerosol backscatter. We describe a method that allows the Rayleigh and aerosol components of the signal to be independently determined using the two edge channels and an energy monitor channel. The effects of Rayleigh scattering may then be subtracted from the measurement and we show that the correction process does not significantly increase the measurement noise for Rayleigh to aerosol ratios up to 10. We show that for small Doppler shifts a measurement accuracy of 0.4 m/s can be obtained for 5000 detected photons, 1.2 m/s for 1000 detected photons, and 3.7 m/s for 50 detected photons for a Rayleigh to aerosol ratio of 5.

Methods for increasing the dynamic range of the aerosol-based system to more than  $\pm 100$  m/s are given.

The theory of the double-edge lidar technique for measuring the wind using molecular backscatter is described. Molecular scattering provides a dependable and reasonably uniform source of signal on a global basis. This is particularly important for making satellite-based wind measurements. In contrast, aerosol-based wind measurements can only provide partial global measurement coverage since large regions of the Southern hemisphere as well as ocean regions have low aerosol concentration. In the molecular method, we use two high spectral resolution edge filters which are located in the wings of the Rayleigh-Brillouin profile. This doubles the signal change per unit Doppler shift, the sensitivity, and gives nearly a factor of two improvement in measurement accuracy. The use of a crossover region is described where the sensitivity of a molecular and aerosol-based measurement are equal. This desensitizes the molecular measurement to the effects of aerosol scattering over a range of winds of  $\pm 100$  m/s. We give methods for correcting for short-term frequency jitter and drift using a laser reference frequency measurement and methods for long-term frequency correction using a servo control system. Simulations for a scanning satellite-based lidar at 355 nm show an accuracy of 2-3 m/s for altitudes from 2 to 15 km for a 1 km vertical resolution, a satellite altitude of 400 km and a 200 km x 200 km spatial resolution.

## REFERENCES

<sup>1</sup>Korb, C. L. and B. Gentry, "New Doppler lidar methods for atmospheric wind measurements - the edge technique", invited paper, Conference on Lasers and Electro-Optics, Vol. 7 of 1990 OSA Technical Digest Series, 322-324 (1990).

<sup>2</sup>Korb, C. L., B. Gentry, and C. Weng, "The edge technique - Theory and application to the lidar measurement of atmospheric winds", *Appl. Opt.*, **31**, 4202-4213, 1992.

<sup>3</sup>Gentry, B. and C. L. Korb, "Edge technique for high accuracy Doppler velocimetry", *Appl. Opt.*, **33**, 5770-5777(1994).

<sup>4</sup>Korb, C. L., B. Gentry, and S. X. Li, "Edge technique Doppler lidar wind measurements with high vertical resolution", *Appl. Opt.*, **36**, 5976-5983, (1997).

<sup>5</sup>Korb, C. L., B. M. Gentry, S. X. Li and C. Flesia, "Theory of the Double-Edge Technique for Doppler lidar wind measurement", *Appl. Opt.*, **37**, 3097-3104, 1998.

<sup>6</sup>Flesia, C. and C. L. Korb, "Theory of the Double-Edge Molecular Technique for Doppler Lidar Wind Measurement", *Appl. Opt.*, **38**, 432-440, 1999.